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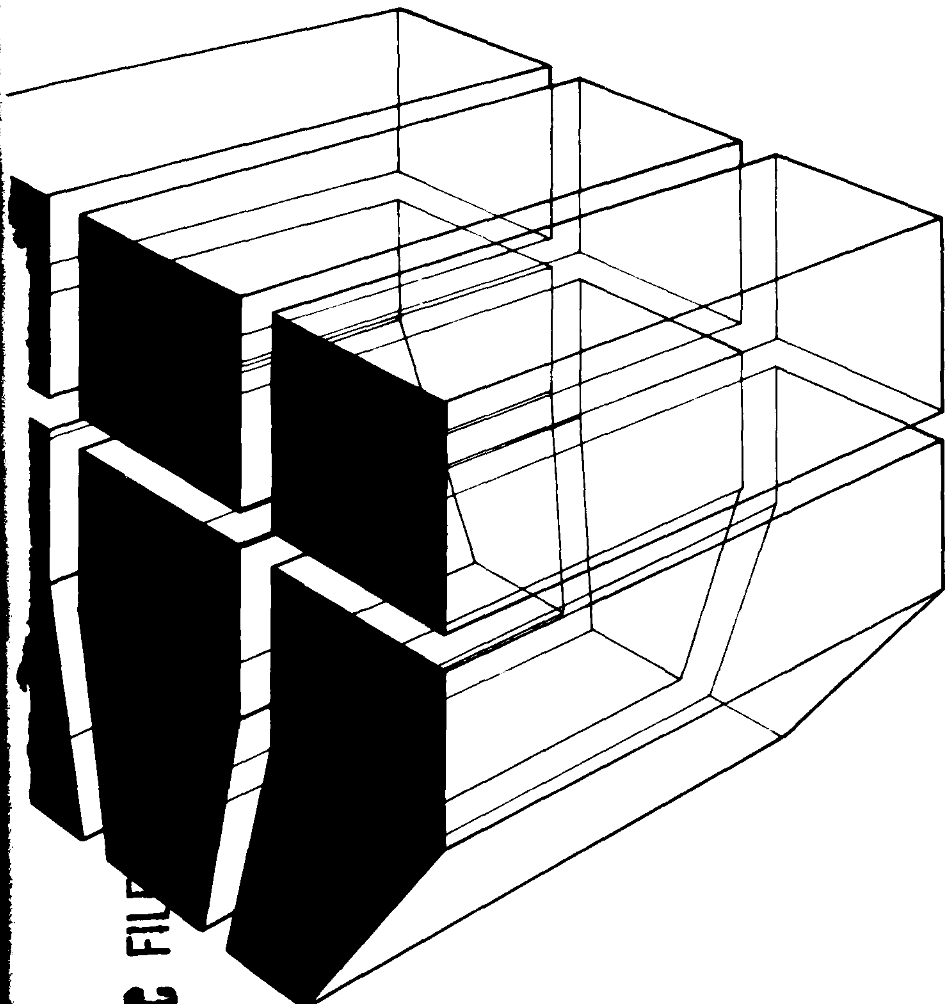
TECHNICAL REPORT P-125
April 1982

MX HIERARCHICAL NETWORKING SYSTEM



by
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This study evaluated four networking and two summarization schemes for use in the MX management information system. Results of the evaluation indicated that the hierarchical networking system and the activity coding summarization technique were superior for meeting user requirements. The report describes how these recommended schemes and techniques can be implemented into MX and provides an example of a network hierarchy.

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FOREWORD

This investigation was performed for the U.S. Army Corps of Engineers, Management Support Office, Corps of Engineers MX Program Agency (CEMXPA), under IAO No. E87-81-7151, "Integrated Hierarchical Networks for MX"; Work Unit 439-QR1.

The work was performed by the MX Team, Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (CERL). Mr. Richard Fraser was the CEMXPA Project Monitor. Mr. E. A. Lotz is Chief of CERL-FS.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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MX HIERARCHICAL
NETWORKING SYSTEM

1 INTRODUCTION

Background

In April 1980, the Corps of Engineers' South Pacific Division asked the U.S. Army Construction Engineering Research Laboratory (CERL) to develop a concept and implementation plan for a system to manage the design and construction of MX Missile System facilities.[1] This general concept study noted the need for a detailed evaluation of the requirements to implement the management system. One area recommended for further study which is discussed in this report is the adaptation of commercial software to provide an integrated scheduling and progress reporting system.

To speed implementation of the management system, a prime criterion was to make extensive use of "off-the-shelf," commercially available software such as Project/2 -- a Critical Path Method (CPM) networking and resource leveling system. Where commercially available software could not completely meet user needs, this report recommends procedures and techniques to enhance the existing commercial software.

Objective

The objective of this study was to evaluate various networking and summarization schemes and select for use in the MX system those which would provide the greatest benefits to the user and be most compatible with system software.

Approach

User needs were investigated so that the systems could be evaluated in terms of how well they could fulfill these requirements (Chapter 2). Four potential networking schemes and two summarization schemes were then analyzed to find which would best satisfy the needs of the MX system (Chapters 3 and 4). Based on this evaluation, the hierarchical networking scheme and the activity coding summarization scheme were judged to be superior for meeting user requirements. A description of how these schemes can be implemented into MX has been provided (Chapter 5).

[1] MX Engineering and Construction Management and Information System Concept -- Concept Overview (Electronic Data Systems, December 1980).

Scope

This investigation is limited to evaluating the flow and structure of scheduling and progress reporting information within the Construction Deployment Management Information System (MIS) and with interface points of other MISs (e.g., Missile System MIS). The principal users of the Construction Deployment MIS are the Corps of Engineers MX Program Agency (CEMXPA), Air Force Regional Civil Engineering (AFRCE), the Office of the Chief of Engineers, and Headquarters Air Force - Logistics and Engineering.

Assumptions and Constraints

This report was based on the following assumptions and constraints which represent the current planning philosophy of the MX Program:

1. The MX Management Information System (MX-MIS) will support the Corps of Engineers and Air Force engineering and construction community. An extensive communications and MIS will be needed by this widely dispersed group.

2. The MX-MIS will automatically interface with the program manager's system being developed by the Ballistic Missile Office (BMO) and the deployment systems being developed by the Site Activation Task Force (SATAF), both Air Force systems (see Figure 1).

3. The MX-MIS will allow more effective use of personnel stationed in the field.

4. Maximum use will be made of standard hardware and software selected to enable expansion and insure compatibility. Project/2 has been selected to provide initial CPM capabilities for the MX-MIS.

5. All Corps offices, Corps contractors, and Air Force contractors will provide network-based (CPM) schedule data in accordance with a pre-established, contractually approved level of reporting.

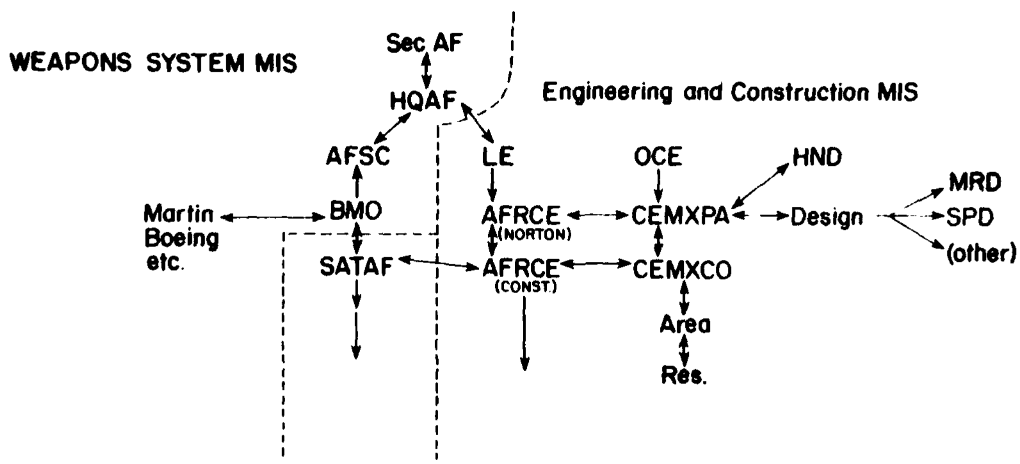

Figure 1. Management information interface.

2 MANAGEMENT CONCEPTS AND USER REQUIREMENTS

The in-place value, speed of construction, and impact on limited resources of MX construction pose management problems never before encountered in civil works or military construction. While relatively effective for normal construction programs, the Corps of Engineers' existing management systems cannot be expected to provide a coordinated management effort for a program as complex as MX.

To meet this need, the Management Support Office of the Corps of Engineers' MX Program Agency (CEMXPA) was tasked with providing a new generation management system for MX. In July 1980, CEMXPA, the Construction Engineering Research Laboratory (CERL), and Electronic Data Systems (EDS) -- a GSA contractor -- surveyed users and evaluated alternative concepts. Their report* recommended a two-path approach to implementation. The first path, anticipated to take about 3 years to implement, recommended a long-range system capable of handling peak construction loads. However, due to the development time required, this approach would not solve the problems of supporting the critical planning phase of the program; therefore, a second-path, interim approach based on identifying and selecting commercial and government hardware/software was chosen that could provide an immediate operational capability. This approach quickly provided users with a computer (initially Boeing Computer Services and later, San Antonio Data Center), terminals, and software (Project/2, a network analysis/resource scheduling system, and Focus, a database management system).

To be effective, the system must give the manager an information network that will support planning decisions and provide some initial construction monitoring effort. The interim system provides both information for planners and an opportunity to field test integration concepts for the final system by validating the procedures recommended in the concept study.

Types of Information

Management needs two basic types of information to make decisions: (1) text in the form of directives, memos, and reports, and (2) network-related information such as project logic, progress, and available resources. This report deals only with network-related information used in Project/2.

Project Logic

Project logic, initially developed as part of the project planning process and later modified as necessary, is a list of (1) all activities and milestones needed to perform the work; (2) interdependencies and logical sequences dictated by how the process must be completed; and (3) durations of activities, usually in the form of workdays. In addition, external constraints are required when the network has availability dates, milestones, or

* MX Engineering and Construction Management and Information System Concept -- Concept Overview (Electronic Data Systems, December 1980).

need dates that are beyond the control of the network and manager. These to a particular time, once the basic logic has determined schedule flexibility (available float).

Progress

Progress is reported as the work is executed. Progress requires as input a reported start date plus at least one of the following: finish date, percent complete, days complete, days remaining. The manager can use this information to compare actual progress to the planned schedule.

Available Resources

Available resources can be money, equipment, materials, or manpower. By comparing available resources with the needs of the preliminary unconstrained schedule, the manager can get a more realistic schedule for doing the work.

To understand how the user's data must tie together, several Project/2 oriented management procedures must be understood. Carrying out a construction program is an iterative process; i.e., the manager must constantly respond to new and increasingly more detailed information. The process can be broken down into three phases: (1) planning, (2) execution, and (3) performance measurement.

The planning phase has two steps: developing network logic, and then scheduling various tasks within that logic. When planning manually, managers tend to combine these steps; however, to successfully use a CPM system such as Project/2, the steps must be split so that only technically valid precedence relationships are created. Establishing parallel network logic rather than unnecessary sequential logic allows the computer to better allocate resources and minimize the project time schedule.

In the execution phase, the user manages the work in accordance with the schedule developed.

In the performance measurement step, the manager reports the project's actual progress, which is then compared to planned progress. The system informs the user of schedule slippages delaying the project and slippages that, if allowed to continue, will delay the entire program. In this phase, the CPM system provides a reporting system for both the manager and higher-level supervisors. It also summarizes the raw data into a meaningful format and provides information about future trends.

If actual work slips significantly from the manager's schedule, he* must then decide how to reallocate available resources within the approved plan. If this does not maintain the schedule, more drastic measures are needed. He must then re-evaluate the original logic or work with other managers to allocate more resources to this work. The final option is to develop alternate logic with other managers to allow this milestone to slip, but make every effort to maintain higher level milestones. This sequence of procedures can

* The male pronoun is used to denote both genders.

prevent unnecessary modification of the network logic or schedule; it will also prevent over-optimization of an individual's sub-network at the expense of the total network.

Organizational Concept

Conceptually, the Corps' management philosophy will continue to allow decentralized management responsibility within the limitations imposed by the need for close coordination on the MX project. The project will be administered by CEMXPA at Norton AFB, CA (Figure 2). Engineering functions will be tasked to existing design districts, with construction supported by the Corps of Engineers' MX Construction Office (CEMXCO) (Figure 3); new Corps area offices will be created as the project progresses.

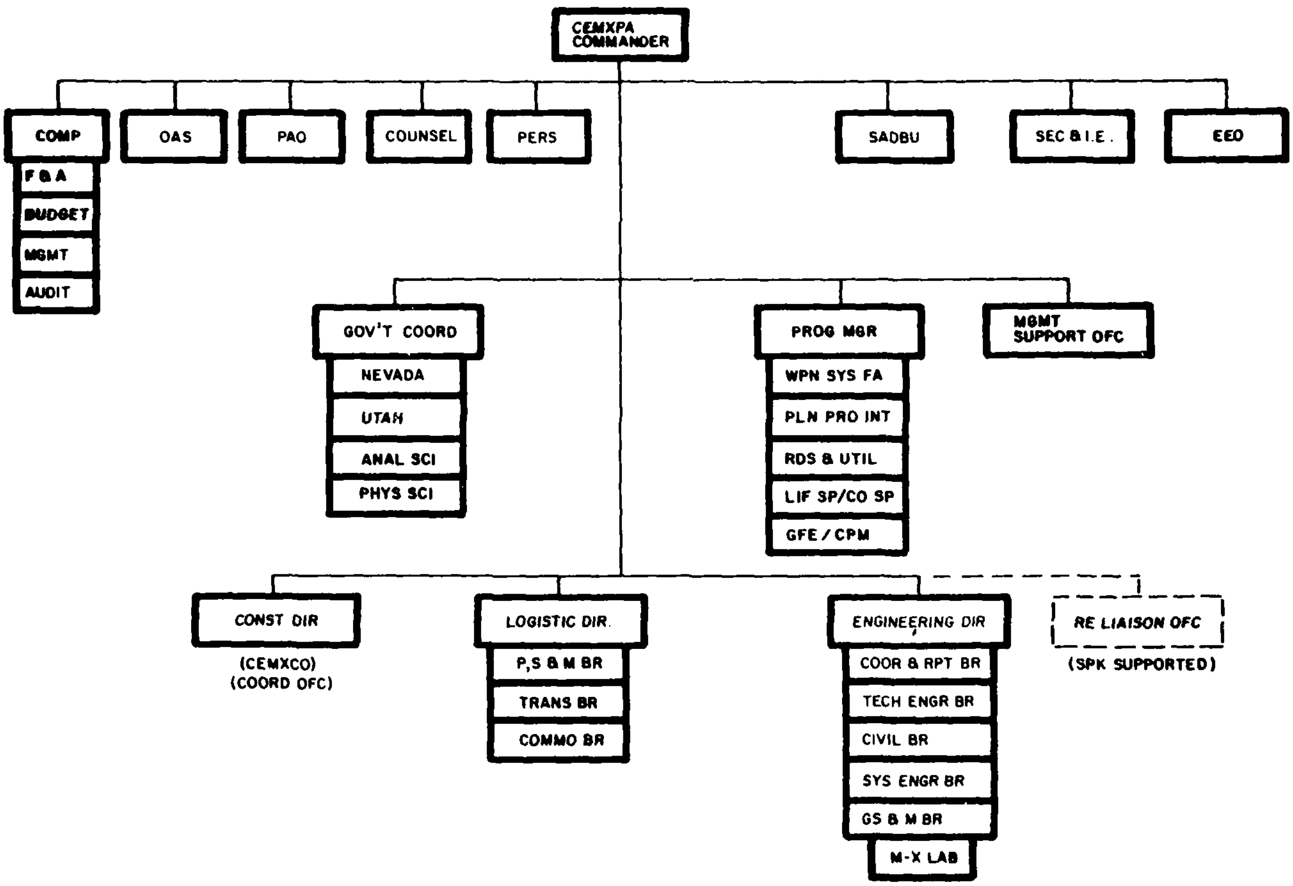

Figure 2. M-X proposed program agency organization chart.

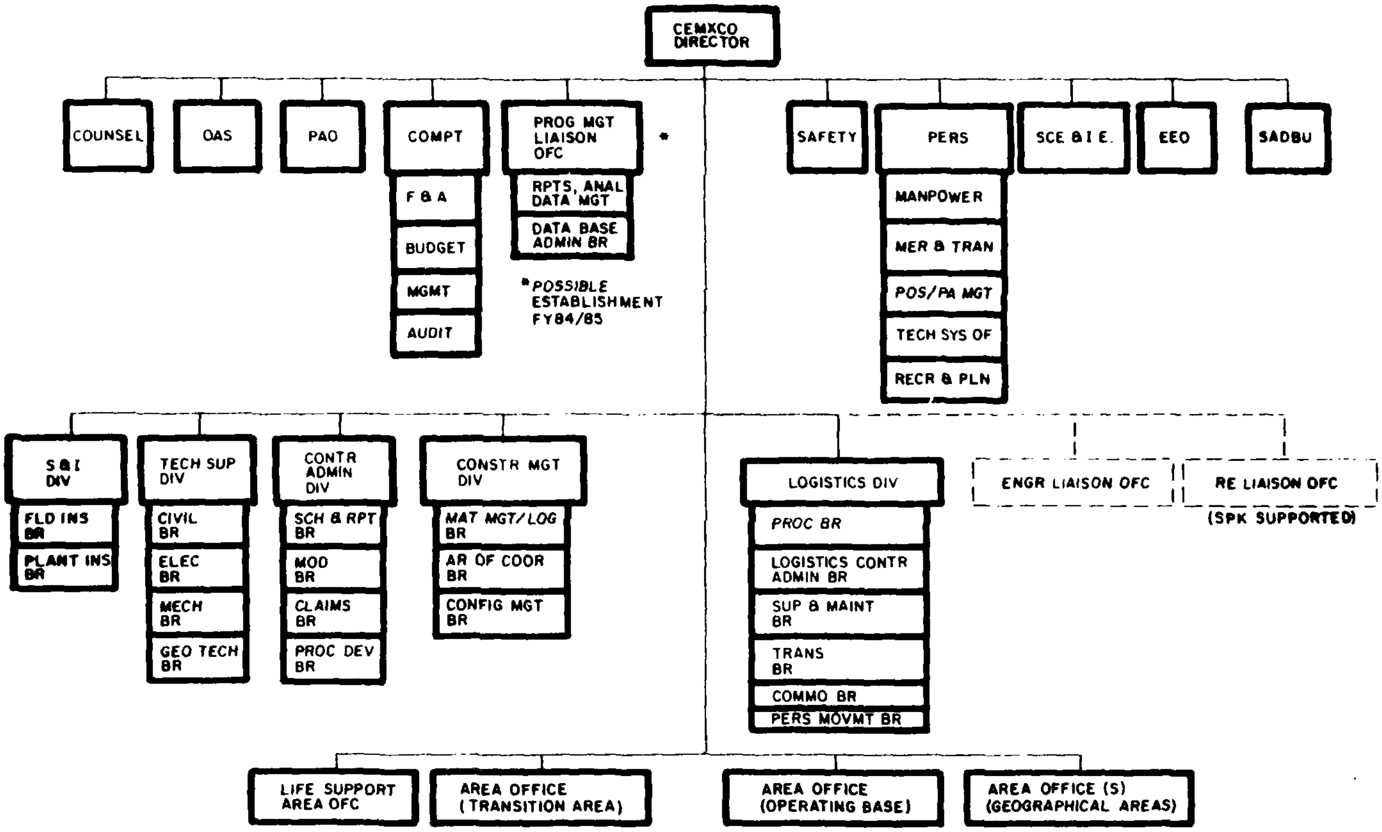

Figure 3. M-X construction office proposed organization chart.

The Air Force Regional Civil Engineers (AFRCE) will act as liaison between the Corps and the Air Force for the MX project. The management system will collect and summarize data for the Air Force, thus freeing AFRCE staff for coordination work. The MIS must provide the AFRCE with access to summarized progress data and give them the capability to respond to congressional or other inquiries with a minimum of "paper shuffling."

Responsibility for Information Quality

Information reporting systems have often failed to provide high-level managers with either timely or accurate information. In fact, the very nature of a "reporting" system can cause most of the problem. The system design often reflects only higher-level management needs. The needs of the person who operates the system -- usually the lowest-level manager or his clerical staff -- are not given adequate consideration. However, if the information in the system is designed to help the lowest-level manager, the data would be inherently more accurate and maintained on a more regular basis, not just at mandatory reporting time.

If the MIS provides the lowest-level manager information needed to successfully do this work, the information needed by high-level managers can easily be collected using automated techniques. The data need only be summarized into meaningful high-level management information to be useful.

Timeliness of Information

During peak loads on the MIS, most information will be related to construction contractors' networks rather than to design or general planning. Upon notice to proceed, the contractor will provide the resident engineer with a network showing how he proceeds with construction. The resident engineer will then review the logic and verify contractual compliance dates. If the network submittal meets the contract's requirements, the resident engineer will approve the network and make it available on the system. If the network is not approved, the contractor must modify and resubmit.

An approved network is the facility's official construction plan. Progress will be reported and contract modifications evaluated against the approved network; interim payments will be calculated automatically based on the reported progress and value associated with network activities. Thus, the network must continue to reflect the project's logic and progress. It is assumed that each contractor will be paid twice a month to reduce the effects of the present cost of money, and payments to contractors will be made on a staggered basis. The currency of the progress information in the system will vary from 1 day to 2 weeks, depending on the specific contract, and assuming progress will be reported only for payment requests.

Information must be more current when projects require close coordination among various MX participants. Each significant milestone which directly affects others must be validated more often as its completion dates approach. This should apply to only a few activities and can be handled as the need arises.

Access to Information

The system has three general types of users: (1) those who generate and maintain information, (2) those who read and approve information and, (3) those who only read the information. Some may feel that there should be a fourth user -- one who reads and modifies information input by others; however, the potential for creating invalid data is extremely high if this is allowed. If information input by others must be altered, the originator of the information should make the changes. Otherwise, second-guessing apparent "errors" can have disastrous effects on the database's quality. If the originator makes the changes, all participants will become aware of and can verify the need for these changes.

It is anticipated that information will flow through the system in several steps. The user responsible for generating the data inputs and edits the information. It is recommended that this be done on a private "scratch" file to prevent accidental destruction of the public database and to keep other users from reading files that are not yet valid. After a file is produced (e.g., approved construction network submittal), it is still recommended that the actual data, such as network progress, be reported to the private file to identify errors before the data is "released" to the public file. Once the data is acceptable, it can overlaid on the previous data without danger of users getting incomplete or improper information.

Security Requirements

By its very nature, an MIS brings together data from many sources, synthesizes them into useful information, and distributes it to various managers. The need to combine the information, and to make it available to anyone who needs it, creates many security problems. Potential controls include: account passwords, program passwords, data files passwords, menu lockout, and independent databases.

Account passwords prevent unauthorized persons from using an individual computer account.

Program passwords allow only authorized users to access a particular program or group of related programs. They prevent unauthorized users from manipulating data (e.g., modifying pay requests).

Data files passwords are usually of two types: Read/write access or Read Only access. Read/write allows a user to create or modify a file while others may be allowed only to read that file.

Menu lockout can prevent an unauthorized user from using certain commands, or accessing data files or submodules of a system. The main advantage of this control is to prevent accidental alteration or destruction of files by someone unfamiliar with the system.

Independent databases is a simple concept for providing security. If the data remains as one file, only the weakest security measures can be used for protection (e.g., menu protection, i.d. protection). However, by separating

data into multiple files, stronger security measures can be used to enhance security.

Anticipated Volumes

Existing networks were analyzed to estimate the size of the network(s) needed to support anticipated MX deployment, particularly for the construction phase. The MX program was analyzed at three levels of detail and the information summarized to determine the number of activities needed.

At the highest level of summary (level 1), the quantities reflect a program manager's information needs. The second level (level 2) reflects the information needed to analyze the deployment masterplan. This is the facilities level of detail. The third level (level 3) reflects the quantities of activities expected at the "contract" level of detail, i.e., the construction activities required for a facility or contract.

Figure 4 lists the total activities expected at each major division of work and the relative level of summary. Figure 5 shows the number of networks envisioned and the probable number of activities needed to represent the MX program, summarized by responsible office.

		No. of Networks	No. of Activities	
Level 1 (Program Summary)			100	
Level 1 SUBTOTAL		1		100
Level 2 (Deployment Masterplan)				
DAA			350	
OBTS			200	
OPBASE			600	
DDA/DTN			1,200	
AUX OPBASE			550	
LIFE SUPPORT			300	
CONSTRUCTION SUPPORT			300	
TEST FACILITIES (VANDENBERG)			60	
EIS/BCP			150	
REAL ESTATE			200	
MISC.			200	
Level 2 SUBTOTAL		11		4110
Level 3 (Contractors Networks)				
DAA	(2 NETS)		6,000	
OBTS	(4 NETS)		4,000	
OPBASE	(90 NETS)		45,000	
DDA/DTN	(45 NETS)		80,000	
AUX OPBASE	(80 NETS)		40,000	
LIFE SUPPORT	(9 NETS)		1,650	
CONSTRUCTION SUPPORT	(18 NETS)		4,000	
TEST FACILITIES	(11 NETS)		5,500	
REAL ESTATE	(18 NETS)		10,000	
MISC.	(3 NETS)		500	
Level 3 SUBTOTAL		280		196,650
TOTAL		292		200,860

Figure 4. Anticipated network volumes.

Office	Number of Networks		Number of Activities/Milestones		
	Unsupported	Supported	Unsupported	Supported	Total
CEMXPA					
Program Summary	--	1	--	100	
Deployment Masterplan	--	2	--	260	
					360
CEMXCO					
Deployment Masterplan	0	3	--	900	900
AFRCE					
Deployment Masterplan	1	0	150	--	150
SPD-RE					
Deployment Masterplan	0	1	--	200	200
SPK-RE					
Aquisition Network	11	0	10,000	--	10,000
SPL-Western Area Office					
Contractor Networks	11	0	5500	--	5500
Logistics					
Construction Support	9	0	2000	--	2000
Construction Support					
Construction Support	9	--	2000	--	2000

* Supported indicates a lower level network feeds data to the network listed.

Figure 5. Network maintenance by responsible office.

Office	Number of Networks		Number of Activities/Milestones		
	Unsupported	Supported	Unsupported	Supported	Total
Design -- SACR/LA/OMAHA					
Deployment Masterplan	5	--	1,755	--	1,755
Area Office 1					
Deployment Masterplan	--	3	--	570	
Life Support Network	1	--	150	--	
Contractor Networks	96	--	55,000	--	55,720
Area Office 4					
Deployment Masterplan	--	1	--	275	
Life Support Network	1	--	150	--	
Contractor Networks	80	--	40,000	--	40,425
Other Area Offices (9)					
Life Support Network	9	--	1,350	--	
Contractor Networks	45	--	80,000	--	81,350
Others					
POGS/Misc.	3	--	500	--	500
	281	11	198,555	2,305	200,860

Figure 5. (Cont'd).

3 POTENTIAL NETWORKING SCHEMES

The application of network-based planning, scheduling, and reporting systems is not new. However, several alternative network-based schemes must be evaluated to determine the best solution for the MX project because of its size, duration, cost, and complexity.

To help determine which networking scheme best meets the MX program's needs, a criteria checklist was developed to weigh the relative merits of each scheme. The criteria reflect MX programs and user requirements identified in the MX Engineering and Construction Management and Information Systems Concept Report. Generally, the criteria addressed the mechanics of how information is loaded in the system, translated into useful information, and distributed through the management organization.

The criteria considered in this report are defined as follows:

1. Single Network Limitation. Will the scheme allow the maximum size network anticipated to be processed in a single computer run?

2. Multiple User. Can multiple users work with their portion of the network simultaneously or are "bottlenecks" likely?

3. Data Security. Can a user's data be protected from alteration or destruction by other users?

4. Data Access. Can a user easily access necessary information?

5. Vertical Information Flow. Does information easily flow vertically through the organization with a minimum of manual effort?

6. Horizontal Information Flow. Are all interfaces between users at any level integrated to provide a coordination effort?

7. Currency of Information. Can users be updated quickly about changes that may impact their work?

8. Turnaround. How quickly can the results of a computer be made available to the user?

9. Ease of Implementation. Given the existing equipment and software, how easily (quickly) can a scheme be implemented?

10. Processing Costs. What is the relative computer cost to provide management information if a scheme is implemented?

11. Overall Cost. What is the relative operating cost (labor, materials and computer) to provide management information if a scheme is implemented? (This does not include relative cost of implementation.)

Single-Network Scheme

The single-network scheme includes all activities in a single network (Figure 6a). It considers all of the relationships between the diverse activities needed to coordinate the project properly. Although this scheme most directly integrates the work of each manager, there are a number of shortcomings.

Information for the entire project is limited to the maximum number of activities allowed by the system (usually 32,000). Processing time and costs are also high because a large amount of data must be processed after every database change. Only one user has access to the data, thus creating an information bottlneck; thus, if multiple users are allowed access, data

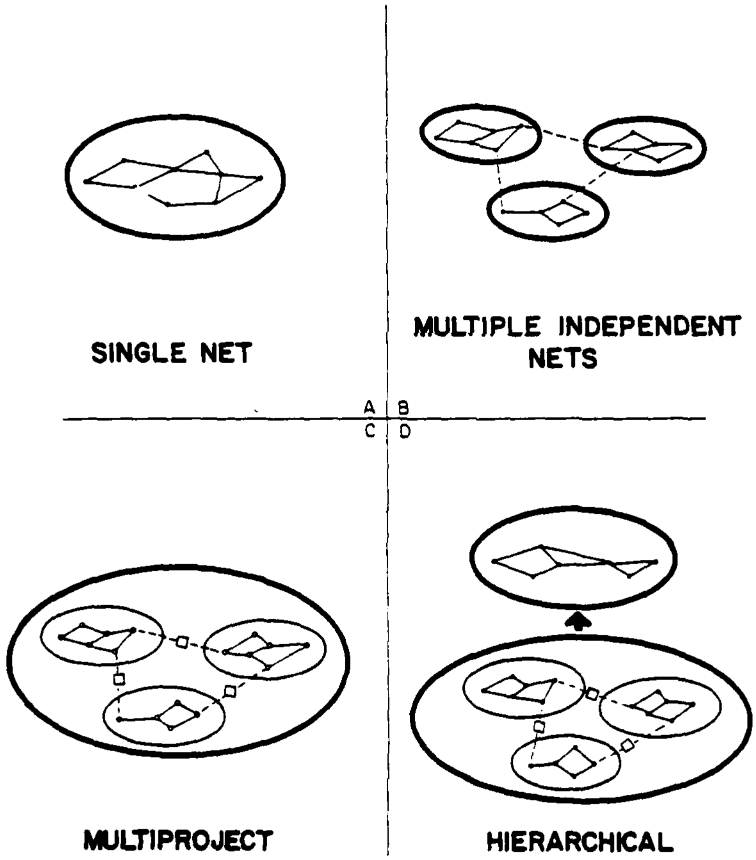

Figure 6. Potential networking schemes.

security is compromised. Finally, to obtain specific data, the user must use multiple selections in order to define a narrower group.

The size limitations could be overcome by varying the network's precision; i.e., near-term activities could be more precisely defined than future activities and old activities dropped as they are completed. This method, which is a sensible basic planning technique, could also be applied to any of the four schemes discussed in this chapter. Future activities can rarely be defined as well as near-term activities, and this additional detail does not necessarily enhance accuracy. In fact, it may add significantly to the planners' workload and give a false sense of detailed knowledge of future activities.

Multiple Independent Networks

This scheme consists of using two or more independent networks to include all network-related information for the MX project (Figure 6b). This scheme increases the total number of activities available to be the product of the maximum number of activities allowed (by the system) in a network times the number of independent networks. Assuming a comparable total number of activities, the processing time and cost for this scheme should be less than that expected for a single network since fewer activities are involved in each network calculation. In addition, more than one user can have access to the system at the same time. The number of users can equal the number of independent networks if necessary.

However, this approach requires both extensive manual communication of interactions between the independent networks and manual combining of information for reports. This manual intervention would be awkward, time-consuming, and could introduce errors.

Multiprojecting

Multiprojecting, which allows multiple independent networks to be processed as a single network, automatically coordinates a project, thus eliminating the need for manual communicating, combining, and coordinating (Figure 6c). Through common milestones, the automated system can temporarily combine individual networks into a single network having the significant attributes of each "member" network.

The advantage of multiprojecting is that many of the problems encountered with processing a single large network are eliminated, yet most of the attributes of the independent network scheme are retained. Retaining individual member networks reduces processing costs and spreads the responsibility for maintenance of each portion of the network among the various managers. Multiprojecting automatically coordinates each member network, thus reducing the manual effort. Under normal conditions, the multiprojecting scheme is constrained to the network size limitations of a single network scheme.

Hierarchical Networks

The previous networking schemes have not addressed the problem of vertical communication within the MX organization. The information flow can be in the form of directives or management summaries that are sent downward to the field, or progress and project changes that are summarized upward.

The hierarchical network scheme provides not only the horizontal communications of the multiproject scheme but also the vertical communications needed when work is split among several field managers (Figure 6d). Although all of the schemes investigated allow the summary techniques common to most CPM processors, they can be awkward and expensive when very detailed information is summarized repeatedly to a higher level. Maintaining summarized information from a detailed network level in a summary data file with multiple read access produces two improvements:

1. The network is only summarized once to reduce future data manipulation for reports.

2. The summarized data can be made available without the raw data, thus reducing the opportunity for higher-level management to "micro-manage."

Information Processing

The flexibility and access to information of all the schemes could be improved if the data were processed through a scheduling module (Project/2) and then submitted to a Data Base Management System (DBMS). The use of a DBMS could provide several advantages over the scheduling system alone:

1. Consistency in data across networks would be improved.

2. Both ad hoc queries and standard reports would be available.

3. Requests for similar data across networks would allow automatic collection and report generation.

4. Non-standard questions from parties outside the Corps/AF organization could be answered quickly and easily.

Evaluation of Networking Schemes

To help evaluate the schemes, the Networking Schemes Evaluation Matrix was developed to weigh the relative merits of each scheme against each user requirement (Figure 7). Each scheme was evaluated and rated subjectively, based on the authors' judgment, for how well it met the requirements. If a scheme was totally unacceptable, it was scored with a zero and not considered. Even if the scheme had a high overall rating, it was not considered if minor modifications to the basic concept did not improve its unacceptable ratings.

The matrix indicates that the Hierarchical Scheme meets user requirements much better than the others. Its only low rating was for the relatively high

Scale

4 Best Scheme
3 2nd Best Scheme
2 3rd Best Scheme
1 Worst Scheme
0 Unacceptable

	Single Network	Multiple Independent Network	Multiproject Network	Hierarchical Network
Size Limitations	0	4	3	4
Multiple User Data Entry	0	4	4	4
Data Security	1	4	4	4
Data Access	0	2	3	4
Vertical Info. Flow	2	1	2	4
Horizontal Info. Flow	4	0	4	4
Currency of Info.	4	1	2	4
"Turn Around"	0	3	3	4
Ease of Implementation	4	4	4	3
Processing Costs	2	4	3	1
Overall Costs	2	1	3	4
	19*	29*	35	40

*Not considered due to unacceptable individual ratings.

Figure 7. Networking Schemes Evaluation Matrix.

computer processing costs, and those were more than offset by the reduction in manual labor and improved data handling.

Use of the most automated version of the hierarchical scheme for the MX project will require expenditures for significant changes to the scheduling system (Project/2); integration of a Data Base Management System (Focus); and development of a menu to help users operate the programs quickly and efficiently. Additionally, the merits of maintaining an accurate database must be weighed against these anticipated development and higher operating costs. Since this system is designed as a management information system, not an accounting system, the user may find that the additional information and accuracy that a DBMS may provide is really unnecessary for most management decisions.

4 SUMMARIZATION SCHEMES

Two summarization schemes were investigated: one groups like activities, and the other generates new (pseudo) activities representing all activities between pre-defined milestones in a lower level network. In both schemes, an activity in the higher level (more summarized) network may represent one or more activities in the lower level network. The logic representing the precedence relations at the higher level (macro logic) may not fully represent those at the lower level (micro logic). The degree to which the micro logic is represented in the higher level network varies with the summary techniques used.

Activity Coding

Activity coding combines lower-level activities with similar characteristics into a single activity. Although most activities will be summarized, some activities and most milestones will have a one-to-one relationship in each network level.

Preassigned activity coding is based on the existing data summarization capabilities of Project/2. Besides being an effective selection/sort mechanism, this scheme is available on the existing system; very little additional data would be required to implement the scheme fully in a hierarchical system. In addition, activity codes and descriptors could be used to generate new summarized activities and to report progress upward without manual intervention.

The major drawback of this scheme is that activity codes can disregard logic at the lower levels and can cause discontinuous progress to be reported -- a situation which may or may not really exist. This situation becomes less of a problem as the level of summarization becomes higher. Another possible problem is automatic generation of summarized network data in an activity-on-arrow (A/A) format. In an activity-on-node (A/N) format, the node number could be generated using the activity code numbers. This technique could also be used to create the "I" node in A/A networks; however, creating a "J" node number that consistently reflects the precedence relationships in the summary networks could be very hard.

One solution is to convert all summary networks to A/N format. Since Project/2 can programmatically convert the data from A/A to A/N, the contractors could submit their networks in either format, and the summarized data would always be converted to an A/N format.

Pseudo Activities

The pseudo activity scheme uses matching milestones at various levels in the hierarchy. Two types of information are created to provide upward reporting of logic and progress automatically. A new (pseudo) activity created between the milestones replaces multiple network paths created at the detailed level. Then a new duration is created for the pseudo activity by calculating the critical path between the milestones.

The greatest advantage to this technique is changes to a lower-level network are automatically incorporated in the higher-level network. Unfortunately, other data tied to the higher-level network must be reported manually (description of activities, codes for manipulating data), and processing costs will probably be higher. In addition, only the USAF PERT-COST scheduling system can process the data in this way. It would be impractical to modify a commercially available system such as Project/2 for this type of summarization.

Summarization Evaluation

The existing activity coding scheme of Project/2 appears superior to the pseudo activity scheme for the MX program. Potential problems with loss of detailed logic can be overcome by carrying integrated or critical logic upward without summarization and insuring that related strings of activities are summarized. In addition, the relative detail from one network level to the next is generally such that loss of micro logic is insignificant.

5 HIERARCHICAL NETWORKING PROCEDURES

This chapter describes how the hierarchical networking scheme can be implemented into the MX project.

When planning a large construction project, a "top down" approach is used to develop the CPM network. First, the major elements are identified to determine the scope of the work; those elements become better defined as more specific information is obtained. In the context of MX, preliminary planning has been done by personnel from several Districts and Divisions to create a feasible plan based on their collective knowledge. As additional information about materials and the construction process to be used becomes available, the additional detail will replace the more general data or omissions in the previous single network.

The large single network can then be replaced by multiple networks (programmatically) grouped by each major element or responsibility. To integrate the "member" networks, common milestones are identified where there is an interrelationship among activities (Figure 8). The common milestones are given identical numbers, descriptions, and codes; this provides the connecting point between the two (or more) networks. When the member networks are combined through multiprojecting into a single network (Figure 9a), each redundant set of milestones is replaced with a unique milestone that ties the networks together. The multiprojected network is then recalculated (reflowed) to provide durations and dates based on the additional interrelationships (Figure 9b).

At this point, the master network represents the interaction of all members. Each planner can then place his member network in the same relative timeframe as the master network by placing artificial constraints on each milestone that interfaces with another member network (Figure 9c). The planner can do this automatically by selecting the applicable interfaced milestones and, with minor programming, convert these milestones into the form of active an input file of constraints. Inserting these constraints in each member network would relocate each network into its proper timeframe, thus allowing the planner to continue working on the original member network in the proper timeframe without modifying the master network.

If an artificial constraint (such as an external need date) creates negative float, the planner should first try to resolve the time problem within the member network. After attempting to solve the problem internally and probably having the master network reflowed to take advantage of any other time reductions, the network would either become feasible, require major changes at a higher conceptual level, require slippage in need dates, or more likely, some combination of these.

If using this iterative process makes the master network feasible, the plan could begin to be executed as planned. Progress would initially be reported by the design Districts, real estate Districts, and environmental staff, and later, as construction contracts are awarded by CEMXCO. The initial progress would be loaded manually, using normal Project/2 procedures; however, as the volume increased, it would be loaded automatically through lower-level, detailed contractor's networks.

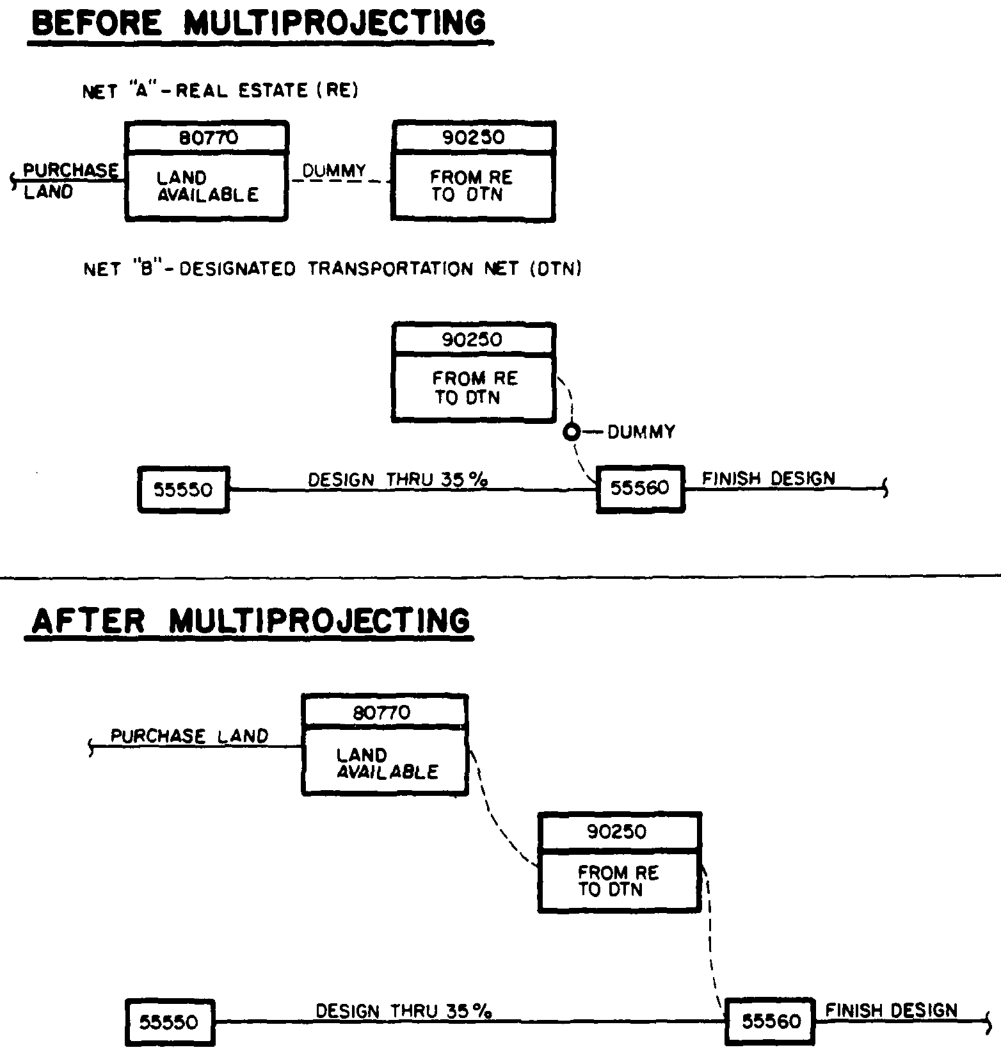

Figure 8. Milestone interface between fragment networks. (Activity-on-Arrow Notation)

As construction contracts are implemented, contractor network submittals will be given, in a machine-readable form, to resident engineers for review and approval. If the submittal is feasible and meets the contract requirements, including system compatibility, the network becomes the official contract network; hereafter, progress data and contract modifications are reported to the network.

Changes to the contract update section of the network logic should rarely require manual intervention at the member network level. Assuming that the contract network will be represented by only a few activities at this level, contract changes should only affect durations, not logic. Most major logic will be developed early in the planning process, not after fixed price (relatively well defined) contracts have been executed. The one exception would be

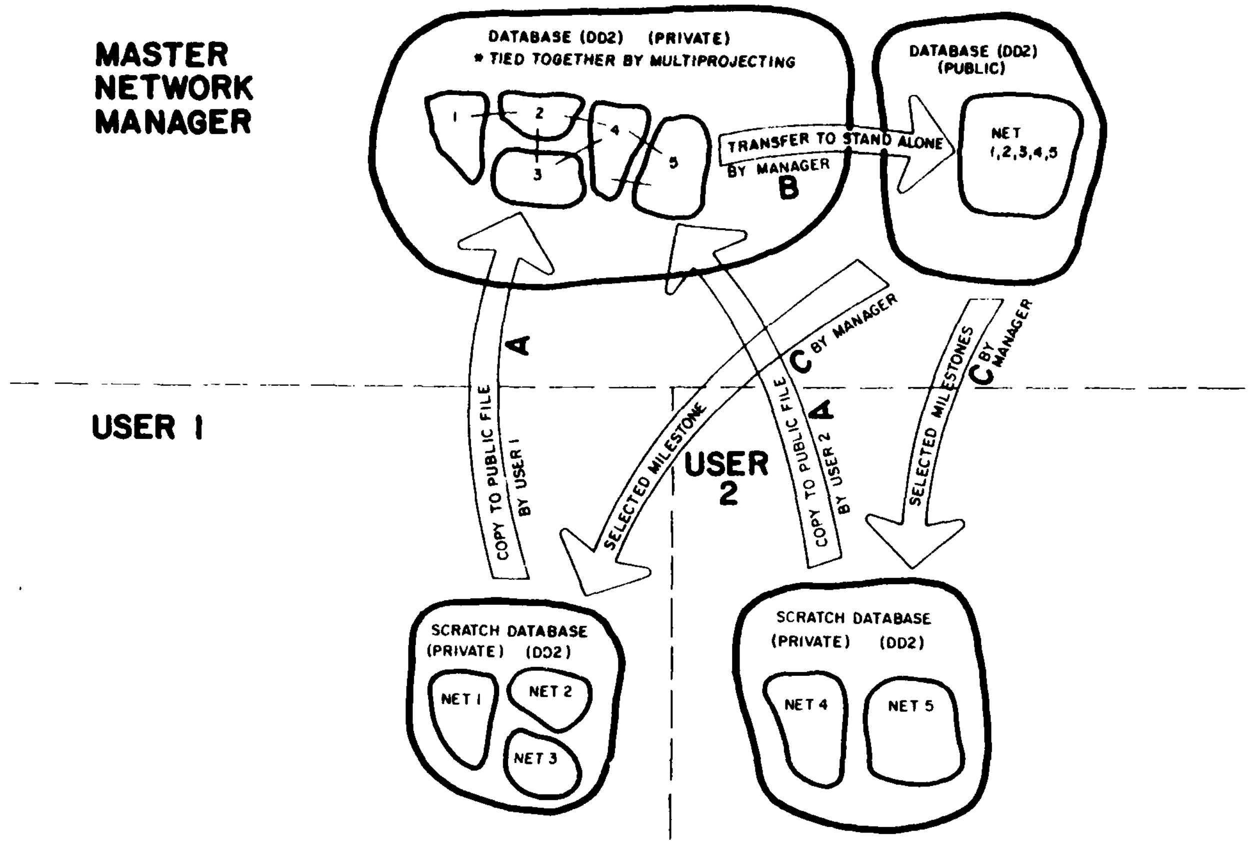

Figure 9. Integrated hierarchical networking using Project/2.

in networks where there are multiple detailed interrelationships between contracts, specifically government-furnished products. Because of the limited amounts of some products or services available, the network logic may undergo numerous changes if the Project/2 resource allocation processor cannot meet contractual need dates.

Once contract progress has been reported to the official file, and summarized progress has been reported to the member network and integrated by multiprojecting if necessary, managers at every organizational level will be able to get summarized reports tailored to the level of detail appropriate for their work. Three basic network levels are anticipated: (1) a program summary network, (2) a summary (member) network, and (3) a contract network with summarization capability through the use of activity coding to tailor a report to any intermediate level.

This example breakdown of the network hierarchy (Figure 10) is based on the proposed Project Management Plan, dated July 1981. The contract level networks represent the probable quantities of networks (and activities) that can presently be expected during the MX construction program. The networks have been grouped and assigned to each area office based on the management plan.

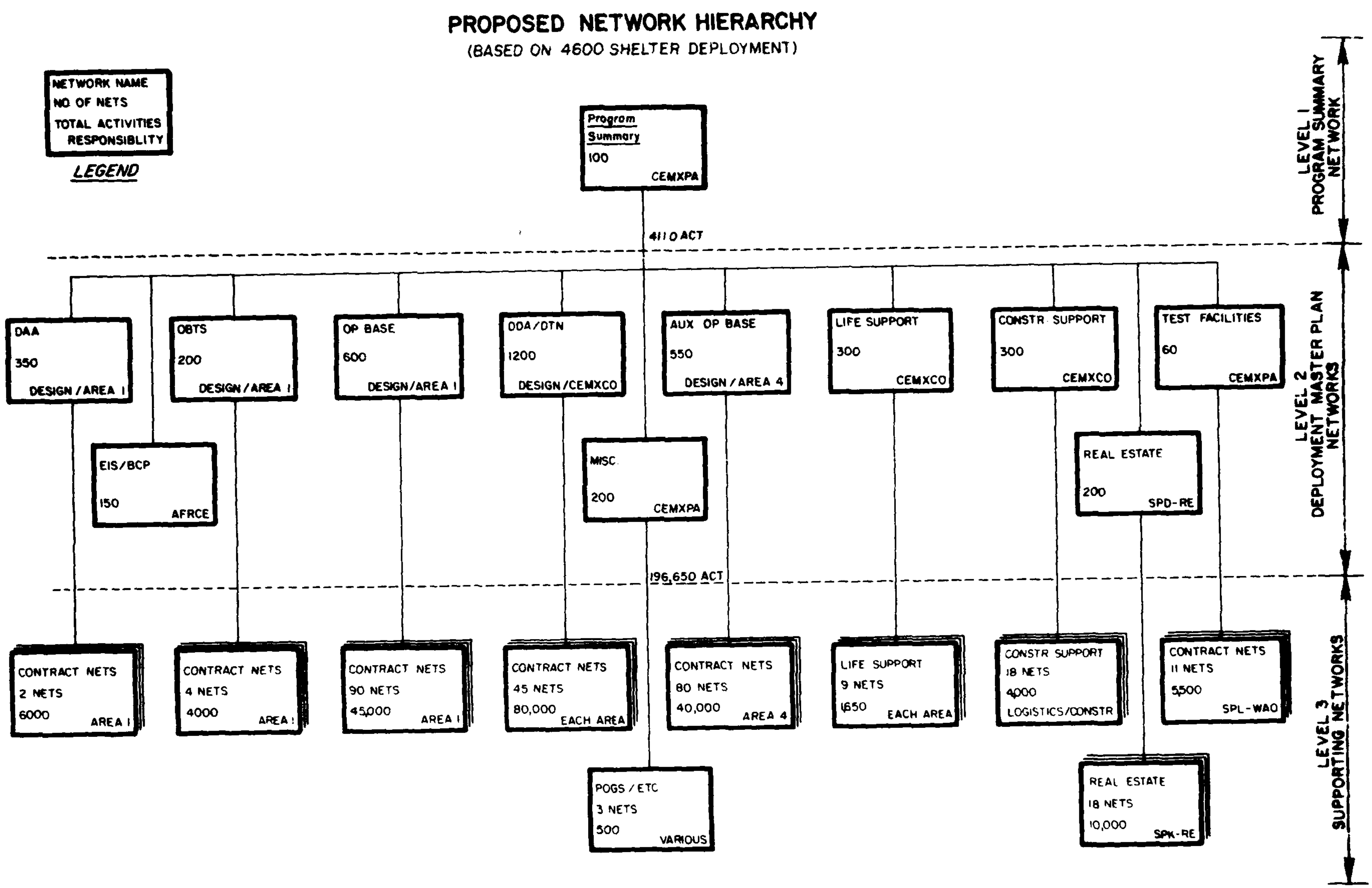

Figure 10. Proposed network hierarchy.

The level 1 program summary is a highly aggregated network which selects only major elements of the construction program. Support activities not directly related to the program would probably not be included; however, they would influence the status of level 1, because they would be integrated at the level 2 member-level networks. This summary would be combined with equivalent information reflecting the status of the weapons system development to provide coordinated high-level briefings.

Since the data is so highly summarized in level 1, it is apparent that some interfaces with Air Force organizations, such as SATAF, must occur at a lower level in the system. A reasonable interface appears to be at the member network level. This level is high enough that CEMXPA would retain some control over the dissemination of information (e.g., release missile shelters to SATF), but provide the necessary coordination in the field.

The member networks in summary level 2 are separated into the major elements of the program and other supporting activities. Contract networks are connected to a member network that they support; this indicates that summarized data will be available for automatic progress updates. Sometimes, member networks indicate that responsibility is split between a design District and CEMXCO. This approach is feasible if the work is cleanly turned over from design to construction. It is more likely, however, that when CEMXCO is staffed, the member network will need to be split. This would eliminate any problems with transferring the network from one office to another.

The third-level networks provide the detail needed to automatically support progress reporting to their respective summarized level 2 network. In most cases, this data is reported from contractor networks but in some cases (e.g., real estate), additional detail was also necessary in noncontract networks. This was done to prevent level 2 networks from becoming unnecessarily detailed and awkward to use.

6 RECOMMENDATIONS

Based on the evaluation of alternative networking schemes, it is recommended that the basic hierarchical networking system with an activity coding summarization scheme be developed to support the MX construction program. In addition, the developers of Project/2 should be contracted to evaluate the feasibility of interfacing Project/2 with an external data base management system.

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